



Sensors

Handheld Spectrometer

Novel lens/chip combination for motionless,
differential linear fresnel microspectrometers

NASA's Langley Research Center has built a very small spectrometer by integrating a differential linear Fresnel lens onto an imaging chip. NASA is using the lens/chip in a very small spectrometer that will be mounted on tires of a rover to analyze soil on the moon or Mars. The spectrometer is useful for space-constrained applications. It combines good resolution with small size and potentially reduced manufacturing costs. The ultra-compact integration of the spectrometer is enabled by the use of an optimized Fresnel grating. Since Fresnel imaging works as valid focal points of spectrum within the short optical distance, the shorter optical path length required (compared to a traditional Fraunhofer lens) enables the small size. Further, the evolution to a differentially linear Fresnel lens (instead of circular Fresnel) avoids the need for aperture slit driver electronics and moving parts, and simplifies manufacturing. The linear Fresnel gratings lend themselves to mass production via plastic injection molding or nano-imprint lithography. NASA is seeking partners to develop the spectrometer for commercial applications.

BENEFITS

- ➔ Is small: As shown in Figure 1, the ultra-compact integration is due to the ultra-small size of the Fresnel grating and its reduced optical path length. The active sensor area is 6.4 0.5 mm² and the chip die size is 9.5 2.5 mm²
- ➔ Has good resolution: the current resolution is 20 nm
- ➔ May reduce manufacturing costs: Fresnel gratings are amenable to mass manufacturing methods such as nano-imprint lithography and plastic injection molding
- ➔ Provides actionable information in the field: the particular combination of good resolution, small size, and cheaper manufacturing is the basis for a practical handheld detector
- ➔ Reduces power requirements: compared to spectrometers with moving parts

technology solution

THE TECHNOLOGY

The Fresnel spectrometer was built by adding a Fresnel grating onto a tiny sensor array micro-chip. As shown in Figure 1d, a half linear Fresnel grating was mounted vertically on one end of a linear imaging sensor. The Fresnel spectrometer uses a gradient line grating with changing gaps and widths as shown. The angle between the imaging detector surface and the grating is 90 degrees. The resolution of the current iteration is 20nm with a spectral range of 200nm ~ 1200nm. Resolution is dependent on the number of gratings. If the number of gratings approaches 200 the resolution would be less than 5nm, theoretically.

Figure 1c shows an actual photo of the linear imaging sensor array chip (Hamamatsu S8378-256Q) that became a platform for building the first prototype linear Fresnel spectrometer. This chip has 256 active pixels in 25 μ m pitch and 0.5 mm height, spectral response range of 200 to 1,000 nm, and maximum operating clock frequency of 500 kHz. Instead of building a spectrometer by putting a detector into a box, NASA built the spectrometer onto the detector chip itself.

NASA has developed a technology demonstrator of the basic spectrometer. In addition to the spectrometer, NASA has a software algorithm to acquire spectrum data and convert it to actionable information.

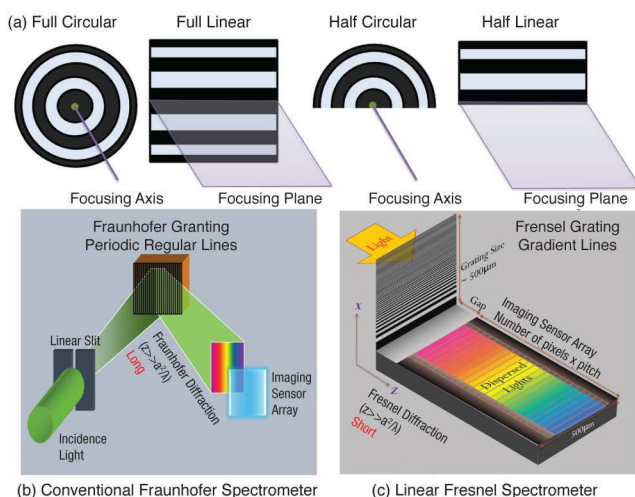


FIGURE 1: (a) Various types of Fresnel gratings (zone-plates), (b) 3-D configuration of conventional Fraunhofer spectrometer and (c) linear Fresnel spectrometer.

APPLICATIONS

The technology has several potential applications:

- ➔ Agriculture - sensing sugar content in fruit
- ➔ Automotive - could sniff engine leads or monitor cabin air
- ➔ Drug-enforcement - for quick narcotics identification
- ➔ Food Processing - checking for salmonella in chicken, e.g.
- ➔ Healthcare - point of use analysis to complement visual inspection (say ah)
- ➔ Personal Protection - devices for soldiers and first responders, for example, to distinguish inert fertilizer from potentially explosive fertilizer
- ➔ Textile Manufacturing - for dye lot quality control

PUBLICATIONS

Patent No: 9,046,418

Choi and Park. Miniaturization of optical spectroscopes into Fresnel microspectrometers. Journal of Nanophysics. SPIE. 2013

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